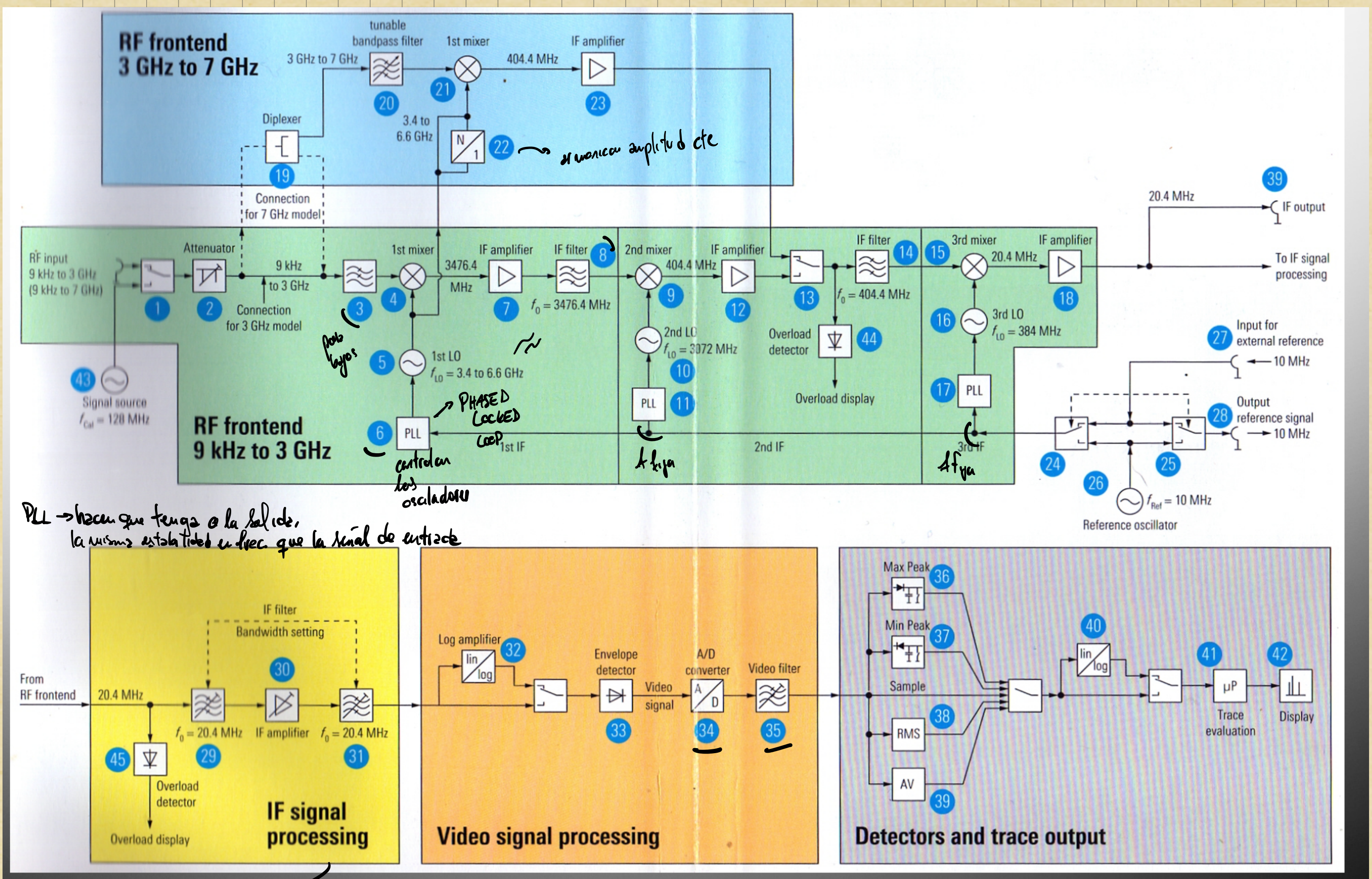
• Segunda clase

Analizador de espectro: para analizar señales que estan muy cercanas en amplitud al piso de ruido.

⤳ heterodino



⤳ armonicas amplitud cte

pasa bajos

⤳ PHASED LOCKED LOOP

controlan los osciladores

f fija

f fija

PLL → hacen que tenga a la salida, la misma estabilidad en frec. que la señal de entrada

reemplazable por un filtro digital

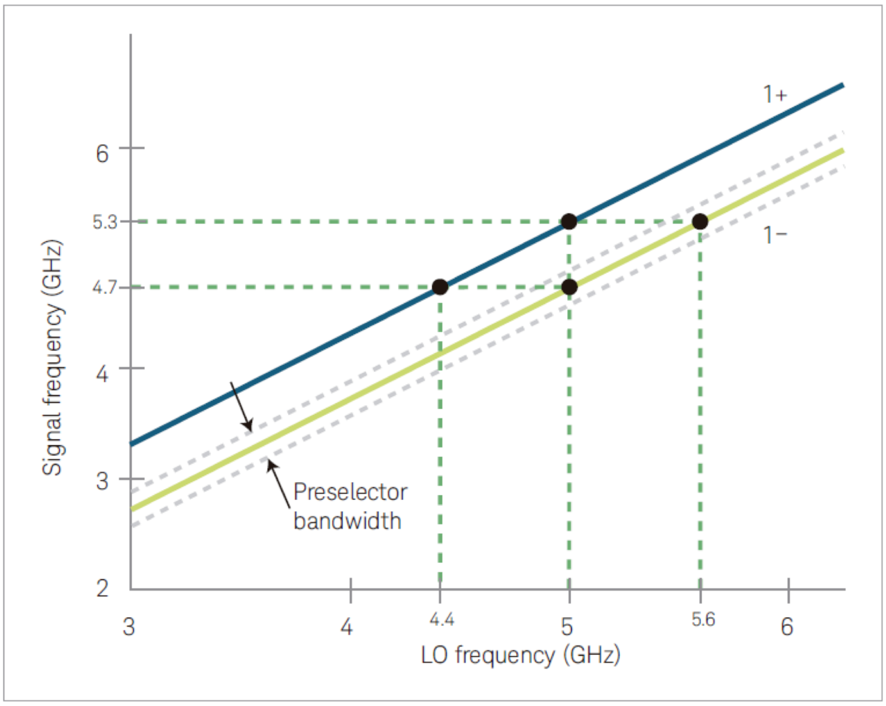
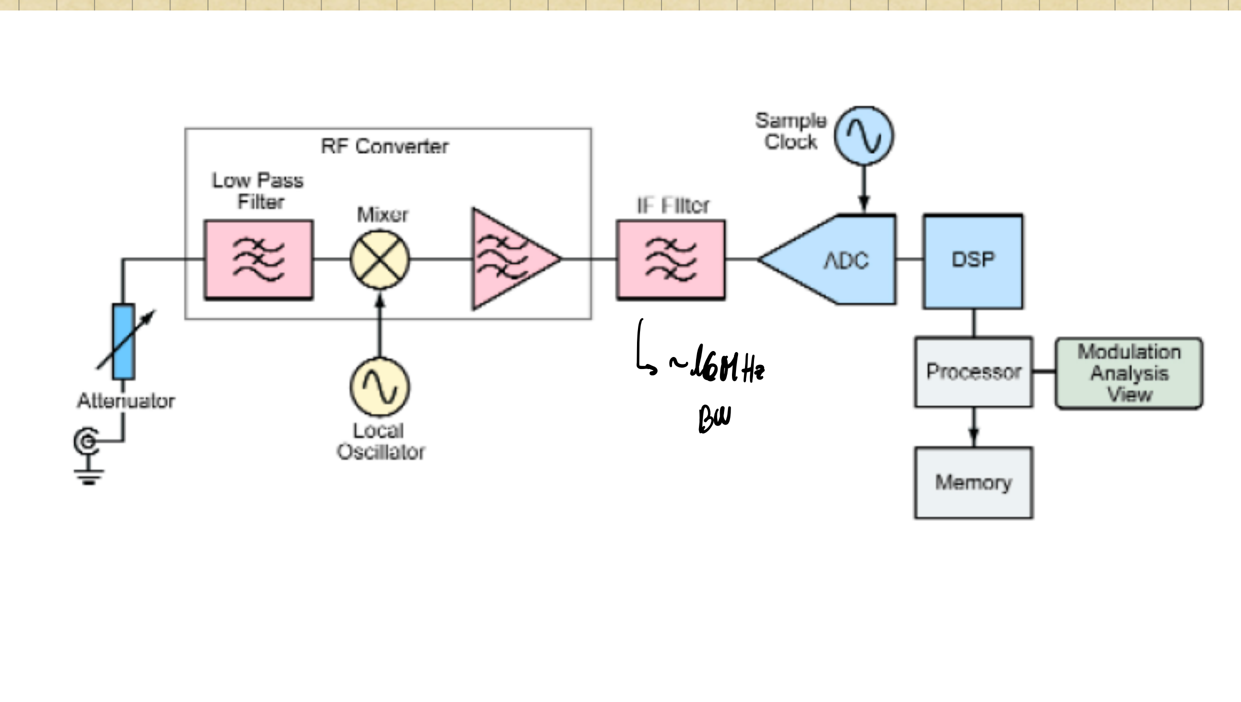
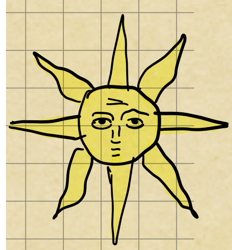


Figure 7-8. Preselection; dashed gray lines represent bandwidth of tracking preselector

Diagrama Analizador de espectro en tiempo real





↑ Resolution BW → ↓ Sensib. piso de ruido

Generación de Armonicas Espurias

¿Cómo se especifican?

Specifications (cont'd)

Spurious Responses

Second Harmonic Distortion

HP 8591E (5 MHz to 1.8 GHz): < –70 dBc for –45 dBm tone at input mixer

HP 8593E (10 MHz to 2.9 GHz): < –70 dBc for –40 dBm tone at input mixer

HP 8594E, 8595E, 8596E (> 10 MHz): < –70 dBc for –40 dBm tone at input mixer

HP 8593E, 8595E, 8596E (> 2.75 GHz): < –100 dBc for –10 dBm tone at input mixer (or below DANL)

Third-Order Intermodulation

HP 8591E (5 MHz to 1.8 GHz): < –70 dBc for two –30 dBm tones at input and > 50 kHz separation

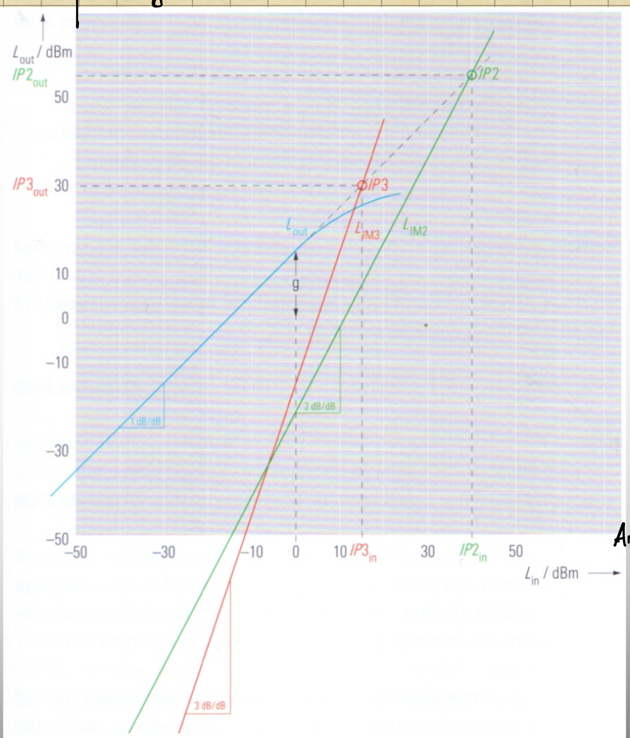
HP 8593E, 8594E, 8595E, 8596E (> 10 MHz): < –70 dBc for two –30 dBm tones at input and > 50 kHz separation

Other Input-Related Spurious (≥ 30 kHz offset, –20 dBm tone at input mixer)

HP 8591E, 8594E, 8595E, 8596E: < – 65 dBc

HP 8593E: < –65 dBc (applied frequency ≤ 18 GHz); < –60 dBc (applied frequency ≤ 22 GHz)

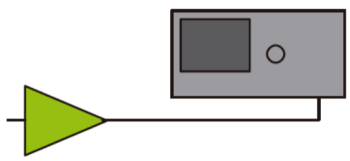
↑ Rango Dinámico



Ancho de Banda

Fig. 5-8 Intercept point of 2nd and 3rd order

Spectrum analyzer and preamplifier



$$IP3_{in,total}(\mathrm{mW}) = IP3_{in,1}(\mathrm{mW}) + IP3_{in,2}(\mathrm{mW}) - 10\ \mathrm{dB} \cdot \lg\left(10^{\left(\frac{g_1 + IP3_{in,1}(\mathrm{mW})}{10\ \mathrm{dB}}\right)} + 10^{\left(\frac{IP3_{in,2}(\mathrm{mW})}{10\ \mathrm{dB}}\right)}\right)$$

(Equation 5-21)

Ganancia del preamplificador

where	$IP3_{in,total}$	3rd order input intercept point of cascaded stages, relative to 1 mW
	$IP3_{in,1}$, $IP3_{in,2}$	3rd order input intercept points of individual stages, relative to 1 mW
	g_1	gain factor of first stage

Fig. 5-10 *Identification of intermodulation products*
a) intermodulation products of DUT (measurement is correct)

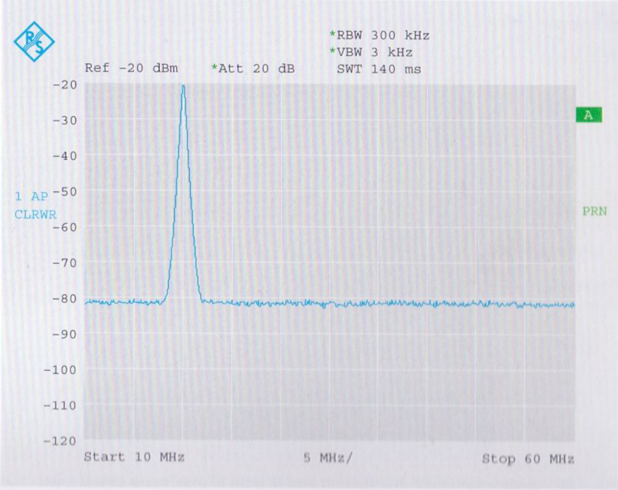
- Al cambiar la intermodulación ...
  bajé la atenuación
  ...

Generación de armónicas espurias

Haciendo un análisis más profundo….
¿y la Sensibilidad?

Jugando con atenuación

b)



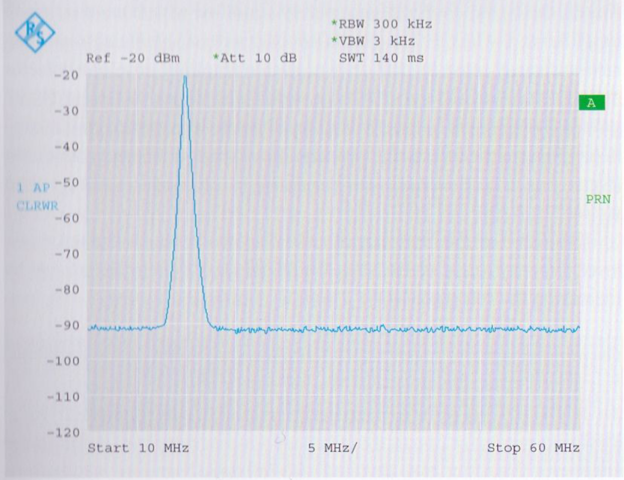


Fig. 4-31 *Single-tone input: dynamic range reduced by too high (a) or too low (b) mixer level. Dynamic range attainable with optimum mixer level (c) shown in comparison*

If the RF attenuation is too high, causing the mixer level to be too low, the signal-to-noise ratio of the input signal will be unnecessarily reduced. As shown in Fig. 4-32, the attainable dynamic range is then reduced by the higher noise floor. Fig. 4-31 shows the effects of the mixer level with single-tone input (see chapter 5.2: Nonlinearities).

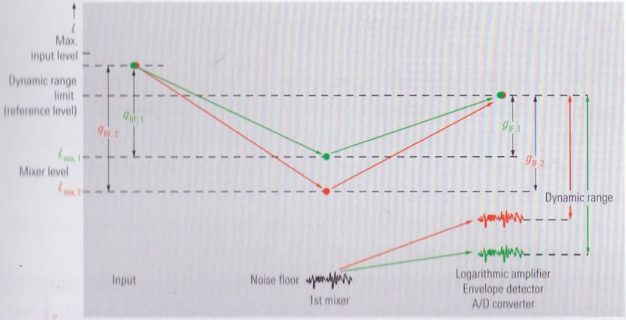


Fig. 4-32 *Dynamic range limited by noise floor as a function of mixer level*

Generación de armónicas espurias

Compresor de Primer Mezclador

Dependiendo de marca y modelo puede estar entre -10 dBm y +3dBm

Para evitarlo el máximo nivel de entrada (Reference Level) tiene que ser claramente menor que el punto de compresión de 1 dB

muy bajos niveles de señal a la entrada

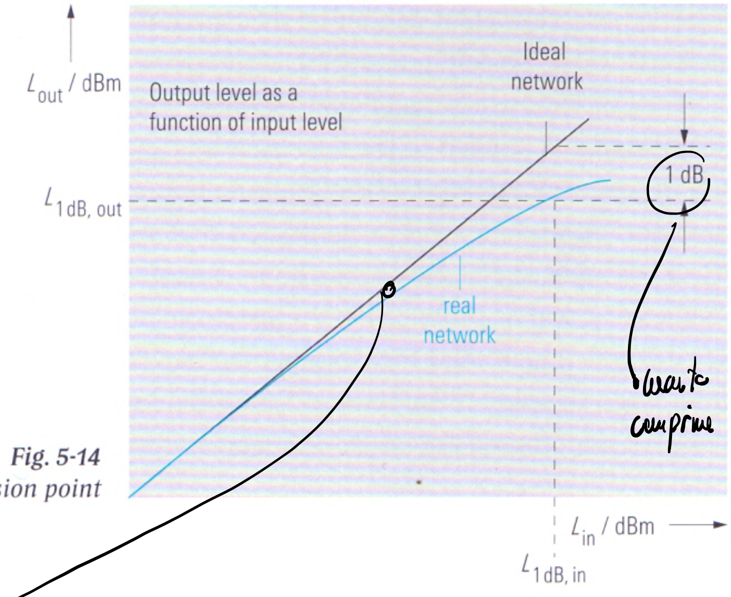


Fig. 5-14
1 dB compression point

lo rompes si no lo cumplís

Maximum input level	
RF attenuation 0 dB	
DC voltage (impedancia entrada)	50 V / 0 V
CW RF power	20 dBm (= 0.3 W)
Pulse spectral density	97 dBµV (Hz)
RF attenuation 10 dB	
CW RF power	30 dBm (= 1 W)
Max. pulse voltage	150 V
Max. pulse energy (10 µs)	1mWs
1 dB compressionn of output level	
0 dB RF attenuation, f >200 MHz	0 dBm nominal

Fig. 5-15
Typical specifications for 1 dB compression point and maximum input level (extract from data sheet)

Inestabilidad del LO

Ruido de Fase…(o FM Residual)

- el ruido de fase no se ve siempre

especif. de esta curva

Spectral purity (dBc (1 Hz)) SSB phase noise, f = 500 MHz	
Carrier offset	
100 Hz	<−90, typ. −94
1 kHz	<−100, typ. −108
10 kHz	<−106, typ. −113
100 kHz[1]	<−110, typ. −113
1 MHz[1]	<−120, typ. −125
10 MHz	typ. −145
Residual FM (f = 500 MHz, B_N = 1 kHz sweep time 100 ms)	typ. 3 Hz

Typical values for SSB phase noise

Carrier offset	f_{in} = 500 MHz	f_{in} = 3 GHz	f_{in} = 7 GHz
100 Hz	94 dBc (1 Hz)	90 dBc (1 Hz)	84 dBc (1 Hz)
1 kHz	105 dBc (1 Hz)	100 dBc (1 Hz)	94 dBc (1 Hz)
10 kHz	113 dBc (1 Hz)	108 dBc (1 Hz)	104 dBc (1 Hz)
100 kHz	113 dBc (1 Hz)	108 dBc (1 Hz)	106 dBc (1 Hz)
1 MHz	125 dBc (1 Hz)	118 dBc (1 Hz)	118 dBc (1 Hz)

1) Valid for span >100 kHz.

Fig. 5-13 Typical specifications for phase noise and residual FM of a spectrum analyzer (extract from data sheet)

$$\Delta F_{RMS} = \sqrt{2 \cdot \int_{f_{off}=0}^{\infty} \left(10^{\frac{L(P_c, f_{off})}{20\,\mathrm{dB}}} \cdot f_{off}\right)^2 \mathrm{d}f_{off}} \qquad \textit{(Equation 5-22)}$$

where
ΔF_{RMS} RMS value of residual FM
f_{off} frequency offset from carrier
$L(P_c, f_{off})$ phase noise level as a function of carrier offset, relative to carrier power P_c and 1 Hz bandwidth (dBc (1 Hz))

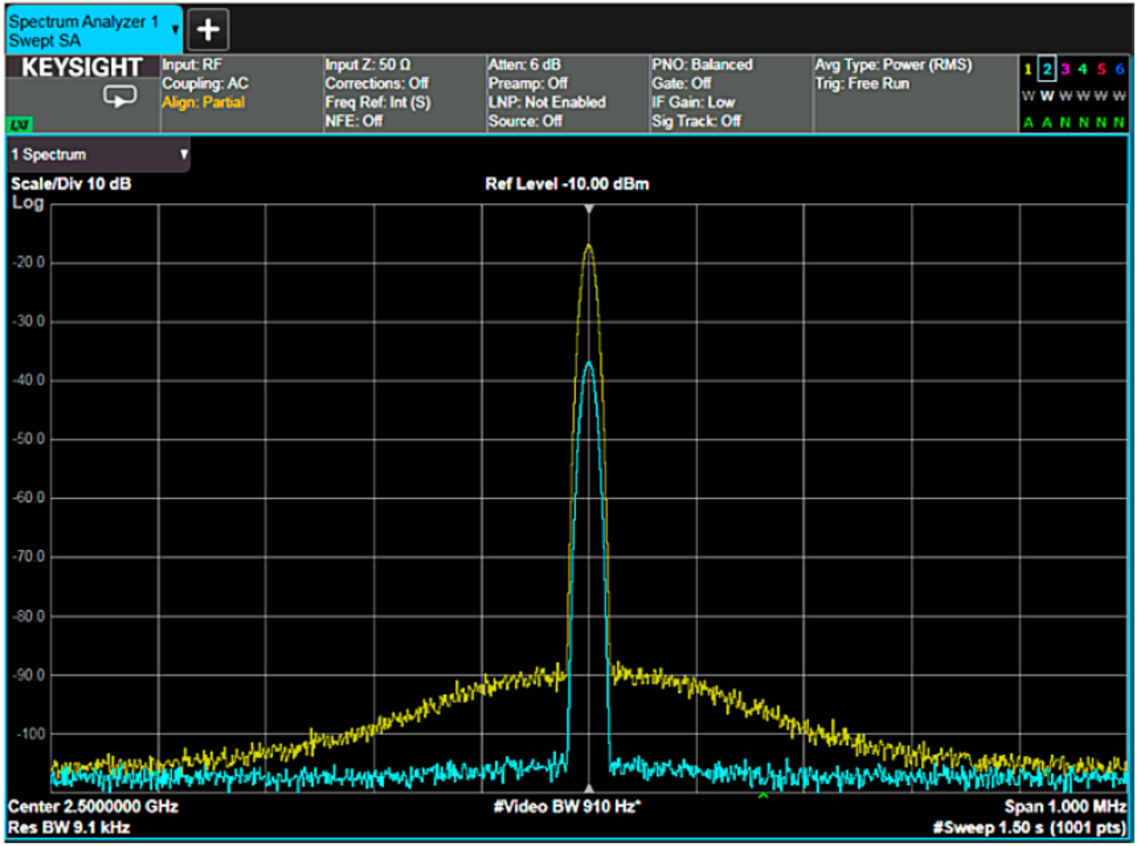
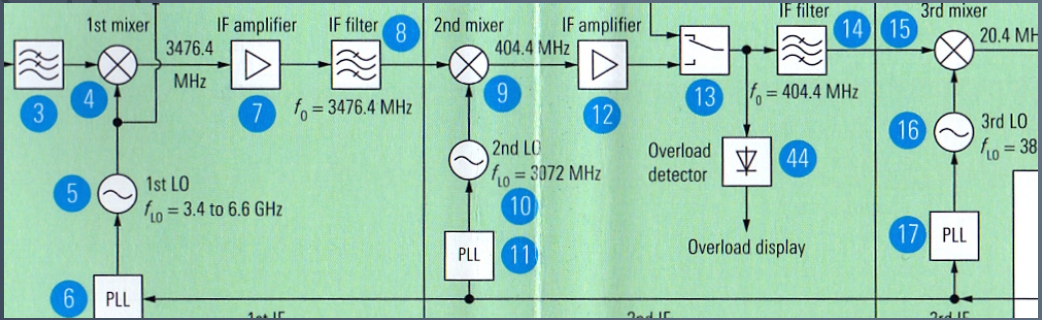


Figure 2-11. Phase noise is displayed only when a signal is displayed far enough above the system noise floor

el ruido de fase queda enmascarado por el piso de ruido

Inestabilidad del LO

Ruido de Fase…(o FM Residual)



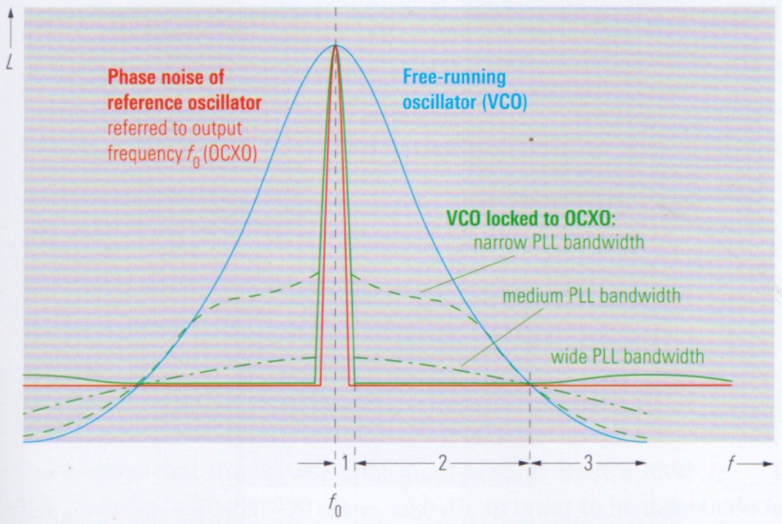


Fig. 5-11 *Phase noise of OCXO, VCO and of VCO locked to OCXO at different PLL bandwidths*

To optimize the phase noise for the specific application, the PLL bandwidth should be variable.

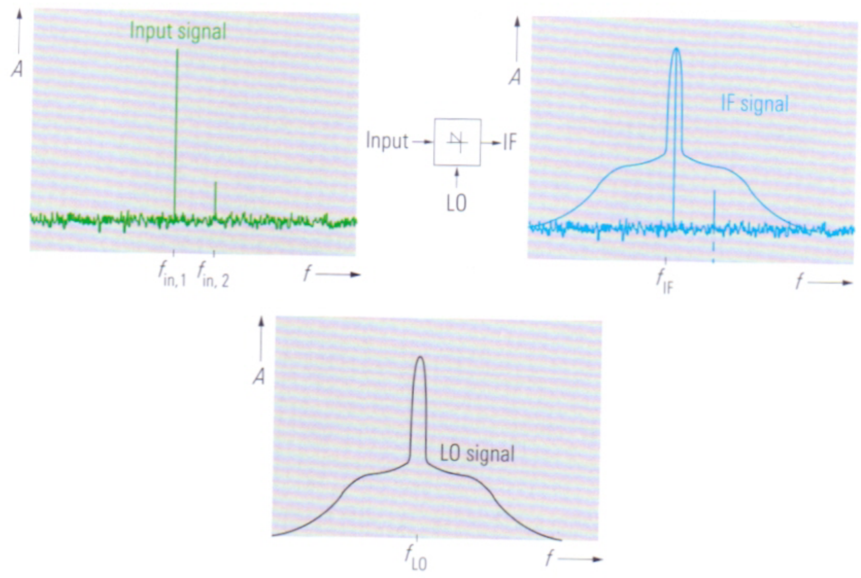


Fig. 5-12 *Internal phase noise transferred onto input signal by reciprocal mixing*

¿Cual es la señal mas grande y pequeña que puedo ver?
RANGO DINAMICO

limites del rango dinamico con diferentes Resol. Bandwidth

HD power mixer → Harmonic Distorsión

indep. de la señal de entrada

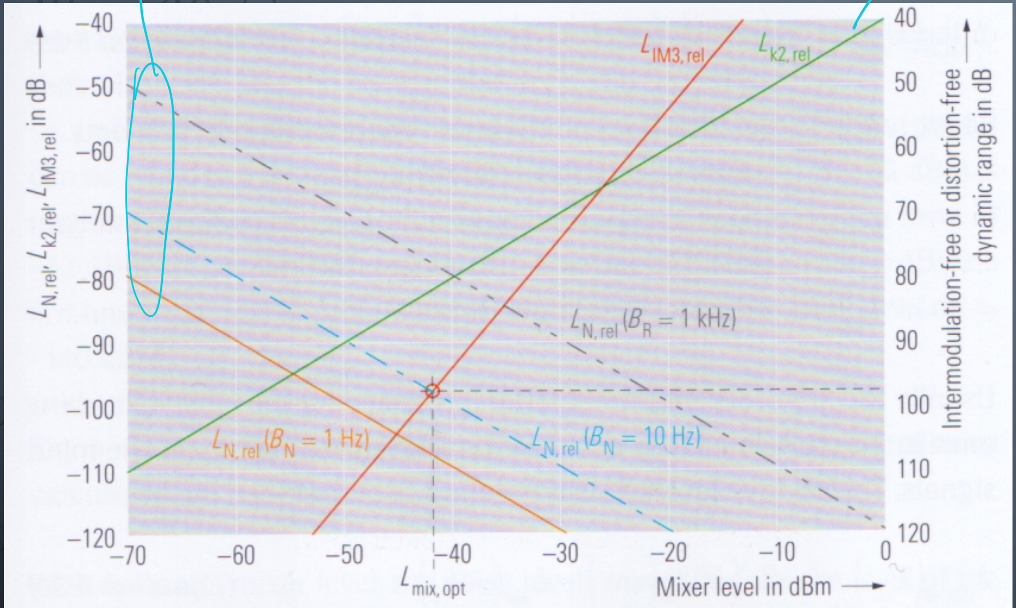


Fig. 5-19 *Intermodulation-free range and maximum harmonic suppression as a function of mixer level (NF = 24.5 dB, $IP3_{in}$ = 7 dBm, SHI_{in} = 40 dBm)*

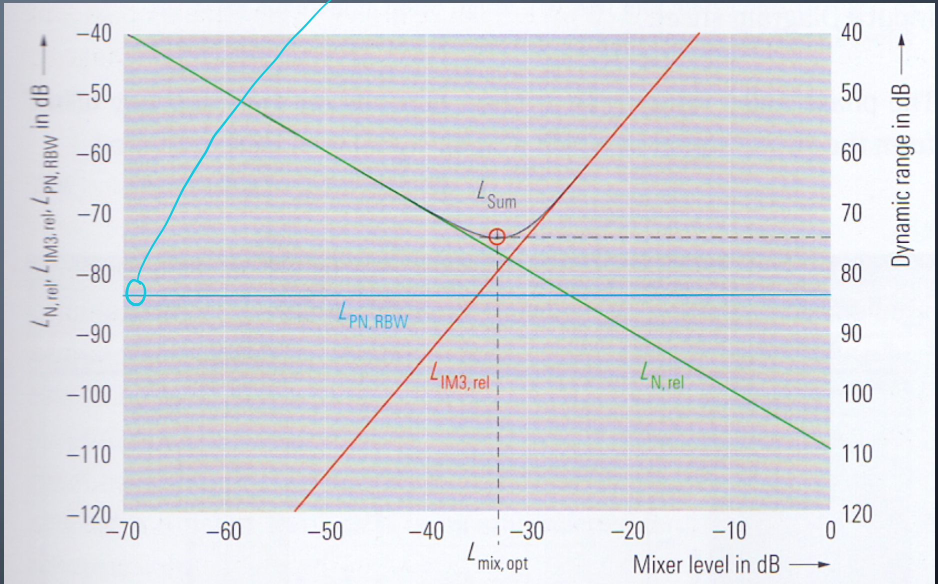


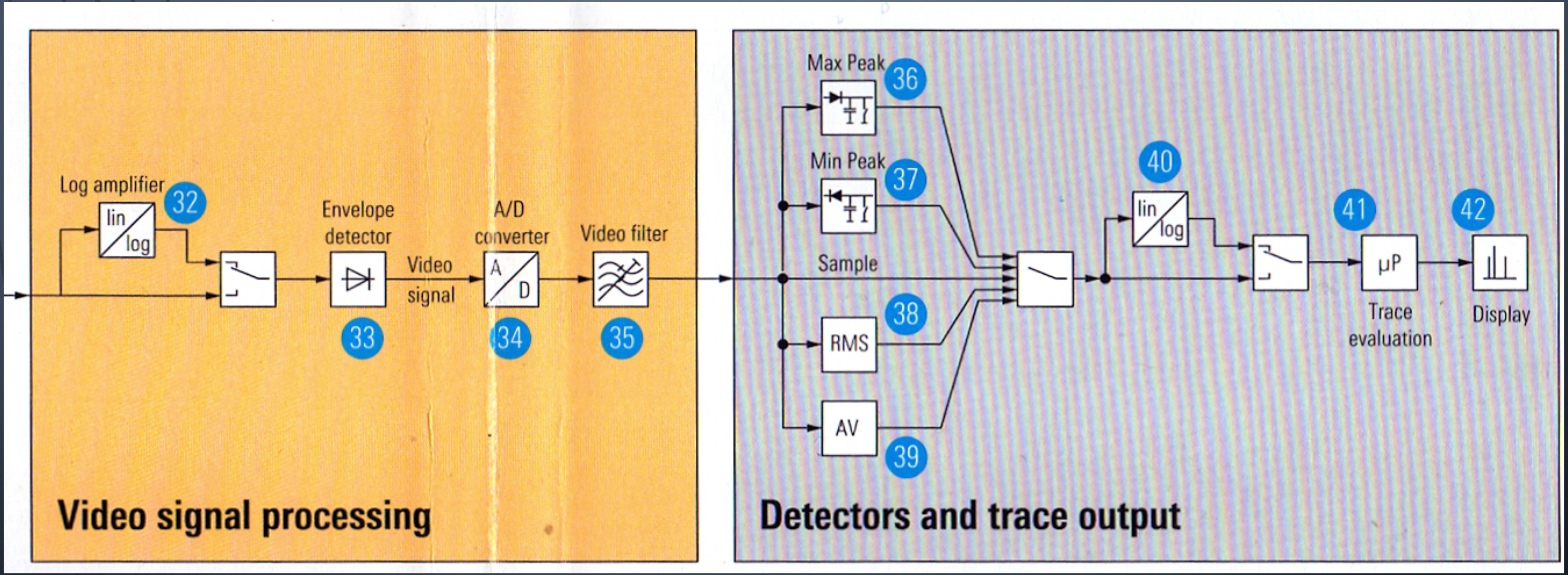
Fig. 5-20 *Dynamic range taking into account thermal noise, phase noise and 3rd order intermodulation products (NF = 24.5 dB, $IP3_{in}$ = 7 dBm, $L(f_{off})$ = −122 dBc(1 Hz), $B_{N,IF}$ = 10 kHz)*

↓ Resol. Bandwidth ⇒ ↓ Piso de ruido

Desacuerdo con Keysight

• ejemplos de mediciones donde se limita por Rango Dinamico y ejemplos donde No pregunta de examen

Detectores (y amplificador logarítmico)



Detectores (y amplificador logarítmico)

a) Crest factor 12 dB ruido Gauss

factor cresta

b) Crest factor 13.8 dB

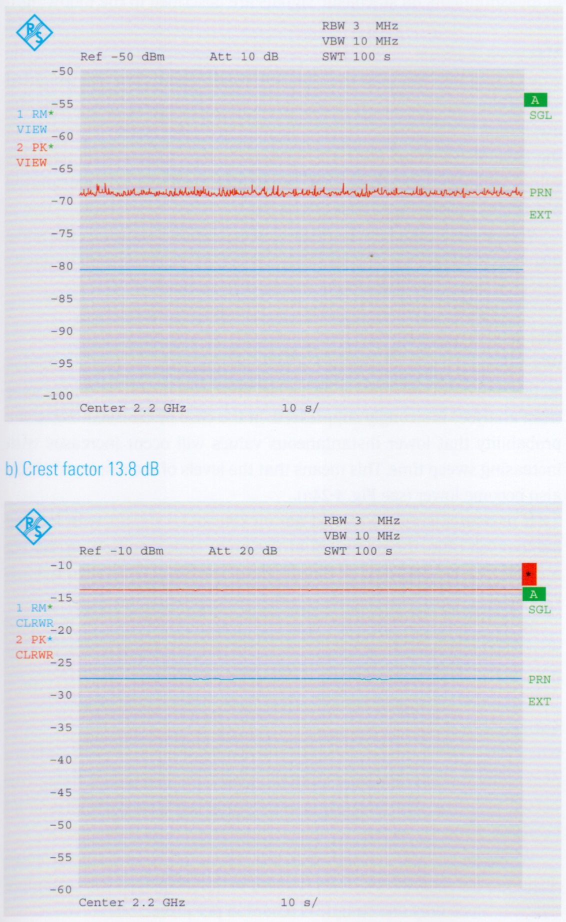


Fig. 4-23 Peak (red traces) and RMS values (blue traces) of Gaussian noise (a) and of a IS-95 CDMA signal (b), recorded with max peak and RMS detectors

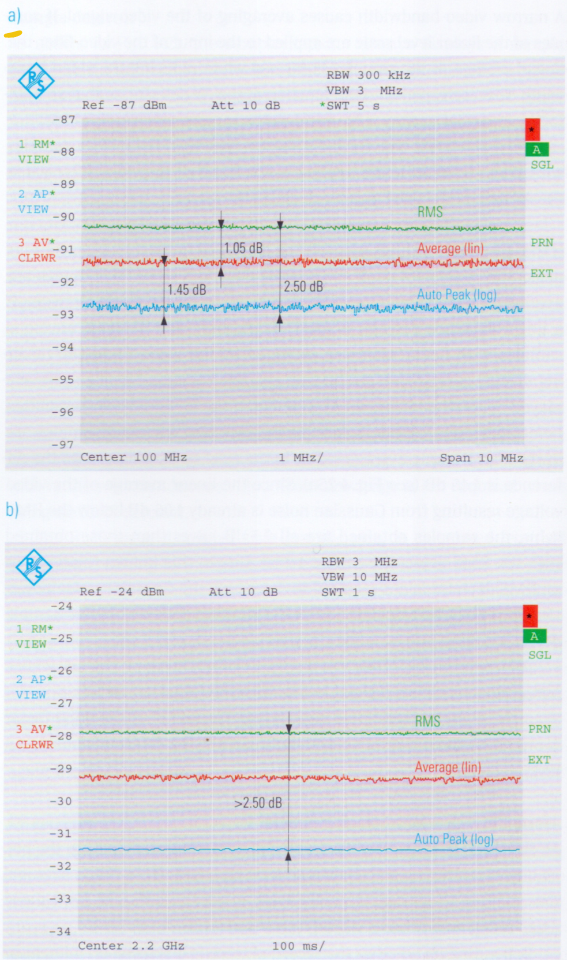


Fig. 4-25 Measurement of Gaussian noise (a) and IS-95 CDMA signal (b) using RMS and AV detectors (green and red traces) as well as auto peak detector with averaging over narrow video bandwidth (blue trace)

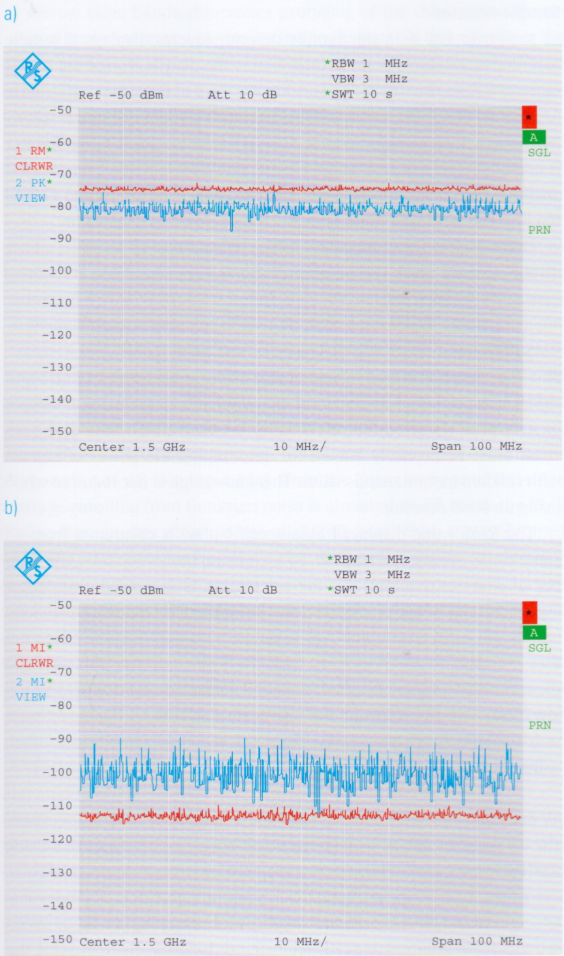


Fig. 4-24 Displayed noise varying as a function of sweep time, with max peak detector (a) and min peak detector (b), sweep time 2.5 ms (blue trace) and 10 s (red trace)

Errores típicos al operar un analizador de espectro

Creer que en la entrada del analizador sólo tengo la señal que veo en pantalla

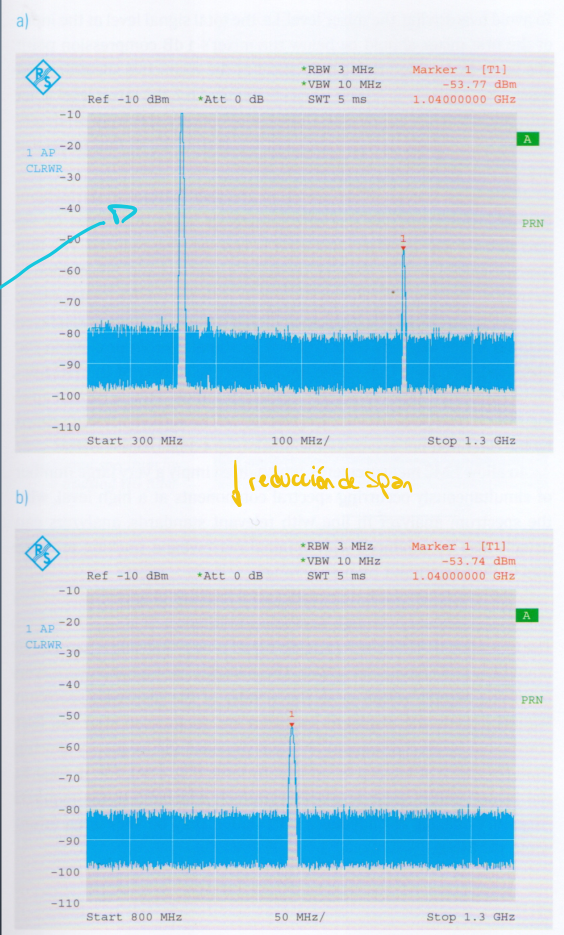


Fig. 4-34 *Spectrum analyzer driven by a sinusoidal signal with f = 520 MHz (a). The second harmonic with f = 1040 MHz that is produced in the first mixer appears even if the fundamental of the signal is not contained in the displayed spectrum (b)*

• Si le quito atenuación al filtro, esta señal me puede quemar el equipo

Errores típicos al operar un analizador de espectro

Elegir mal el filtro de video (no pensar el tipo de señal a medir)

hace que mida mal

In modern spectrum analyzers, the video bandwidth can be coupled to the resolution bandwidth. When varying the IF bandwidth, the video bandwidth is automatically adapted. The coupling ratio (the ratio between resolution and video bandwidth) depends on the application mode and therefore has to be set by the user (see chapter 4.3). In addition to the user-defined entry of a numeric value, the following options are often available:

- Sine $B_N/B_V = 0.3$ to 1
- Pulse $B_N/B_V = 0.1$
- Noise $B_N/B_V = 10$

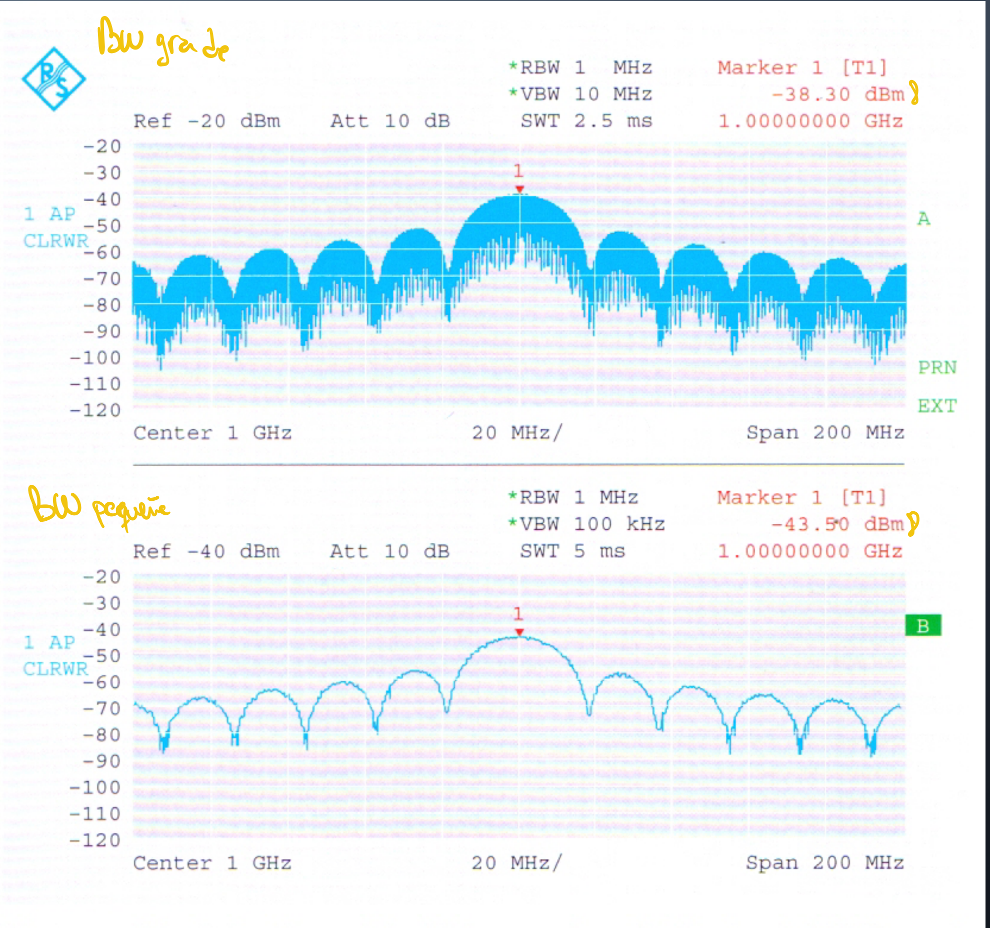


Fig. 4-20 *Pulsed signal recorded with large and small video bandwidth (top and bottom half of screen); note amplitude loss with small video bandwidth (see marker)*

Errores típicos al operar un analizador de espectro

Saturar alguna etapa (overdriver)

The spectrum analyzer described here has overload detectors at the 2nd and 3rd IF so that overdriving of the analog IF processing stages can be indicated (44 and 45).

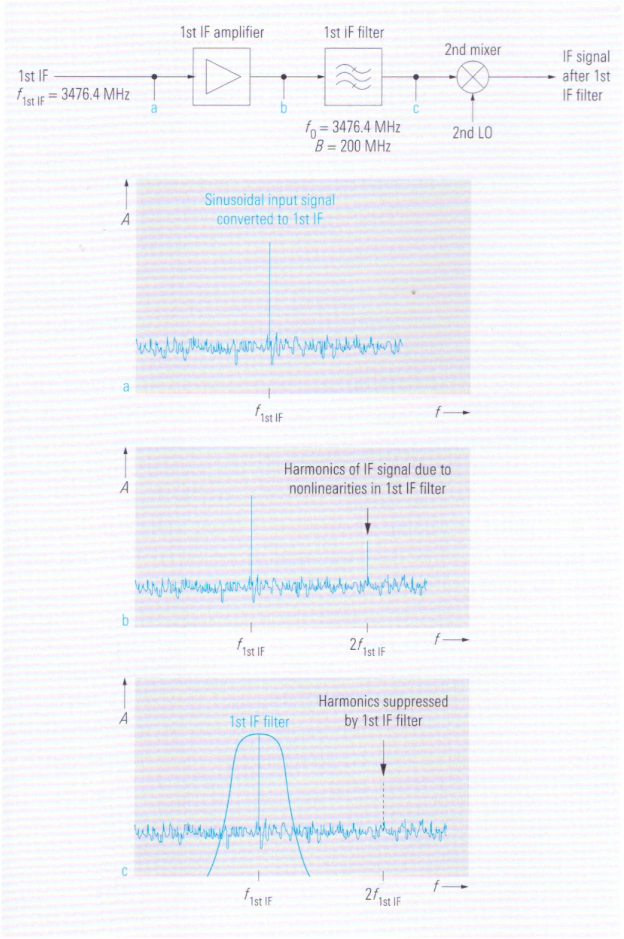
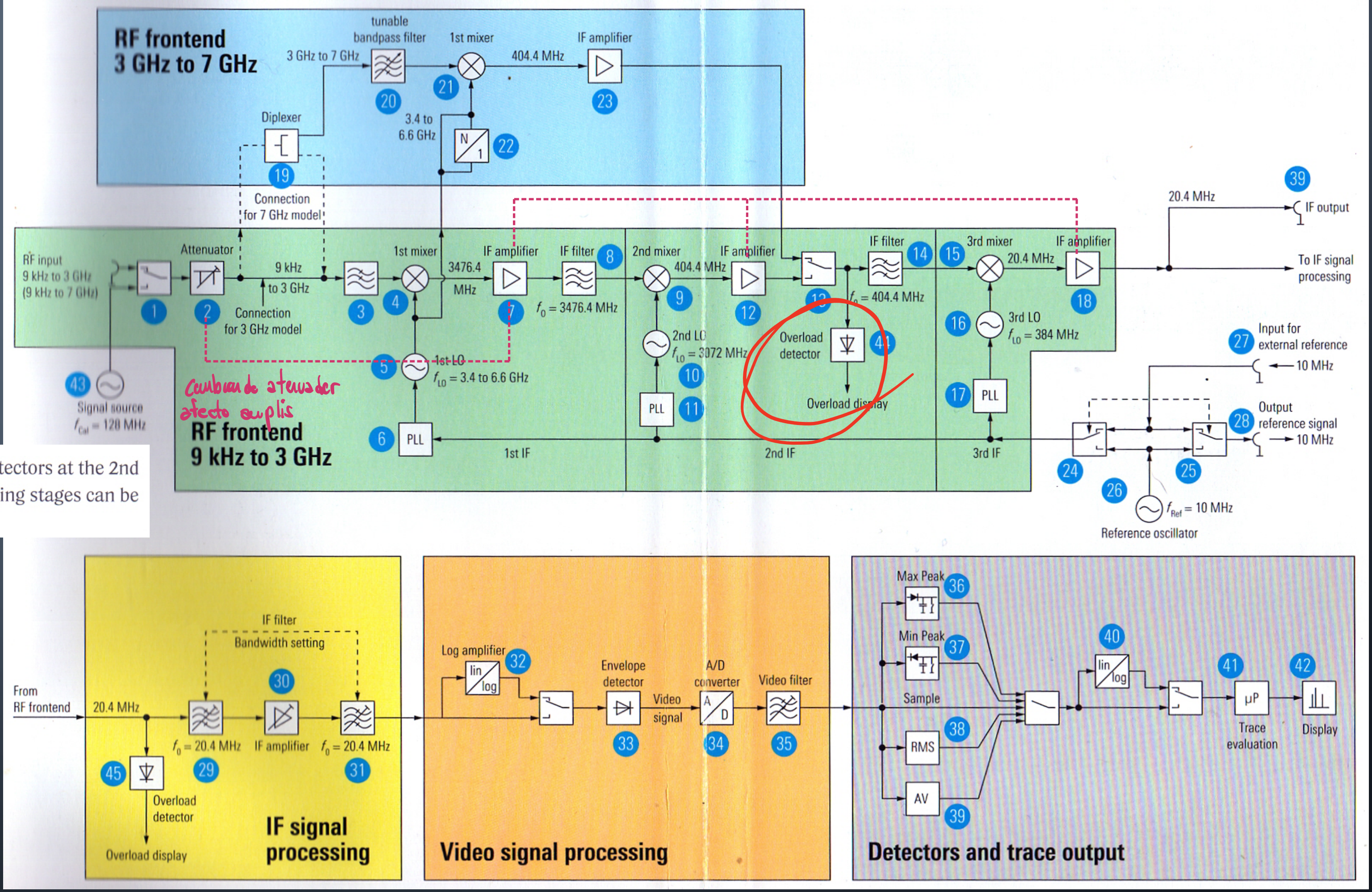


Fig. 4-37 Suppression of distortion products produced in analog IF signal processing components

Errores típicos al operar un analizador de espectro

- Saturar alguna etapa (overdriver)



The spectrum analyzer described here has overload detectors at the 2nd and 3rd IF so that overdriving of the analog IF processing stages can be indicated (44 and 45).

Errores típicos al operar un analizador de espectro

Saturar alguna etapa (overdriver)

En este caso el A/D… , cambiar atenuación para solucionar

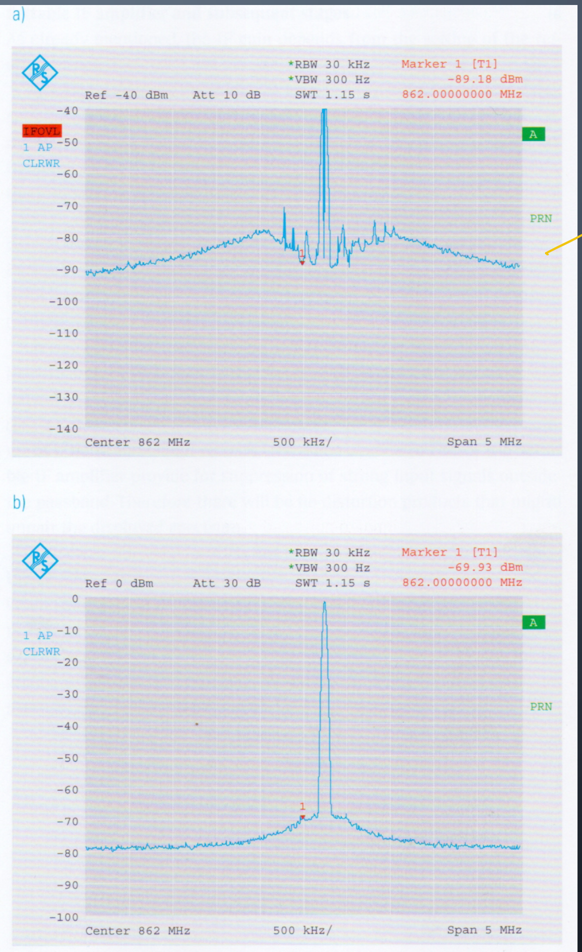


Fig. 4-39 *Mixture products due to overdriving of A/D converter converter when using digital IF filters or FFT filters (a); displayed spectrum in case of correct driving (b)*

piso de ruido de fase sube y baja?
alguna etapa está saturada

Errores típicos al operar un analizador de espectro

Saturar alguna etapa (overdriver)

No siempre es malo….

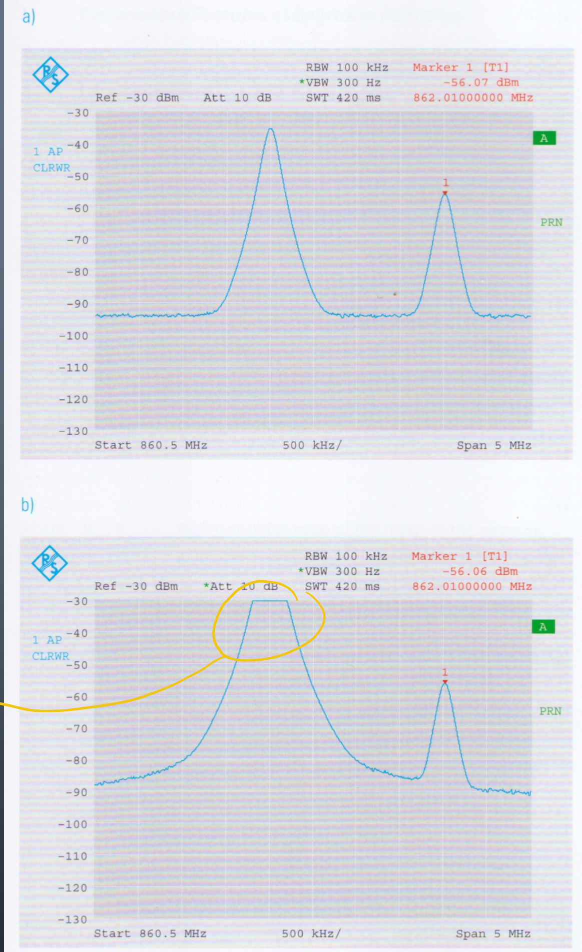


Fig. 4-38 *Level measurement on a weak input signal signal in the presence of a very strong signal, with normal driving (a) and overdriving of the settable IF amplifier (b). Overdriving has no effect on the measurement result*

Si ese pico no es armonica del primer pico

OK para medir el segundo pico

Incertidumbres en amplitud

Table 4-1. Representative values of amplitude uncertainty for common spectrum analyzers

Amplitude uncertainties (± dB)	
Relative	
RF attenuator switching uncertainty	0.18 to 0.7
Frequency response	0.38 to 2.5 → ripple de etapas
Reference level accuracy (IF attenuator/gain change)	0.0 to 0.7
Resolution bandwidth switching uncertainty	0.03 to 1.0
Display scale fidelity	0.07 to 1.15
Absolute	
Calibrator accuracy	0.24 to 0.34

BANCO DE MASCHWITZ

Nombre Completo: Rodrigo Vazquez

Fecha: 2/05/2023

Monto: UN MILLON DE PESOS

$ 1.000.000

A la orden de: Pago de Haberes

LS

Firma